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A SMALL, MATURE MALE *ARCHITEUTHIS* (CEPHALOPODA: OEGOPSIDA) WITH REMARKS ON MATURATION IN THE FAMILY

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Abstract.—A small, functionally mature male *Architeuthis* (gladius length = 179 mm) is described from the Straits of Florida. Aspects of development and reproduction of male architeuthids are discussed.

Several unusual cephalopods were found during a study of the feeding ecology of the broadbill swordfish, *Xiphias gladius,* in the Straits of Florida. Among these were the fragmentary remains of a small squid that was assigned to the family Architeuthidae based on characters of the mantle, fins, gladius, and viscera. The specimen was a mature male with fully developed genitalia and the remains of two ruptured spermatophores.

This specimen (ML = 167+ mm, GL = 179 mm) is the smallest functionally mature *Architeuthis* known. Its size and state of maturity raise several questions regarding the life history of the "giant squid."

Abbreviations and measurements are as defined by Voss (1963) and Cohen (1976).

Historical Resumé

There have been numerous accounts of specimens belonging to *Architeuthis,* but only six functionally mature males (with spermatophores) have been reported. Steenstrup (1857) reported a specimen of *A. dux* (TL > 377 cm) from the western Atlantic. In a later paper (1882), he indicated that the specimen was a male with "seminal capsules" (spermatophores). Sasaki (1929) reported a specimen of *A. japonica* (ML = 1100 mm) from Japanese waters. Voss (1956) described a specimen of *A. physeteris* (ML = 612 mm) from off the Mississippi Delta. Knudsen (1957) reported on a specimen (ML = 1010 mm) identified as *Architeuthis* sp. from Danish waters. Kjennerud (1958) described a mature architeuthid (ML = 1000 mm) from Norway. Roper and Young (1972) reported a small male (ML = 664 mm) from the east coast of Florida in the collections of the Rosenstiel School of Marine and Atmospheric Science, University of Miami. Subsequent examination of this specimen (UMML 31.1762) revealed the presence of spermatophores.

Other reports of male architeuthids include Storm (1897), ML unknown, Joubin (1900), ML = 460 mm, Brinkmann (1916), ML = 1310 mm, Nord-

gård (1928), ML = 1370 mm, Frost (1934), ML = 1560 mm, and Clarke (1962), ML = 385 mm. These reports did not mention the state of development of the genitalia or whether spermatophores were present. The sex of Frost's poorly illustrated specimen remains in doubt (Lu and Roper, pers. comm.). Another doubtful record is that of Owen (1881), identified as *Plectoteuthis grandis* (=*Architeuthis* sp.). His material, consisting of an arm fragment, was considered by Steenstrup (1882) to be a hectocotylus.

Prior to our specimen, Clarke's record represented the smallest adult or pre-adult *Architeuthis* of either sex.

Roper and Young (1972) reported on two juvenile *Architeuthis,* a male (ML = 45 mm) and a female (ML = 57 mm), both with undeveloped genitalia. This is the only report of juveniles from this family.

Iwai's (1956) account of two small architeuthids (ML = 92 mm and 104 mm) is a misidentification (Roper and Young, 1972).

Results

Description.—One male, ML = 167+ mm, GL = 179 mm (from stomach of *Xiphias gladius,* female, 205 cm lower fork length), sportfishing vessel WILDCATTER, Straits of Florida off Fort Lauderdale, 21 June 1978, UMML 31.1761.

Mantle cylindrical anterior to fin insertion, tapering posteriorly to acute point; mantle wall thickest dorsolaterally (3.5–4.0 mm), becoming thin over midline of gladius; anterior margin damaged.

Fins long (FLI = 48), moderately wide (FWI = 40), thick medially, tapering laterally, damaged marginally. Fins diverge anteriorly, insert on dorsolateral wall of mantle, converge posteriorly, insert on dorsal midline of mantle and gladius, terminate in acute point. Fin musculature discontinuous across dorsal midline, separated by narrow longitudinal strip of elastic connective tissue (Fig. 1A).

Funnel damaged; funnel valve and organ missing.

Funnel-mantle locking cartilage straight and simple.

Nuchal cartilage strong, long (NCLI = 14) and wide, with strong raised median ridge bearing longitudinal cleft; base thin, broadly rounded anteriorly and laterally, pointed posteriorly (Fig. 1B).

All structures of *head* anterior to posterior wall of cephalic cartilage missing.

Gladius strong; vanes long (VLI = 84) and narrow (VWI = 11) with narrow anterior shoulders widening posteriorly to form gently curved, convex, lateral margins; vanes widest in anterior ⅓, narrowing posteriorly, entire gladius becoming V-shaped in cross section in posterior ⅓ with lateral borders of vanes and rachis thickened; posterior tip damaged; free rachis short (FRLI = 16) and moderately broad (FRWI = 6); terminating anteriorly in acute point; borders of free rachis parallel for most of its length (Fig. 1C).

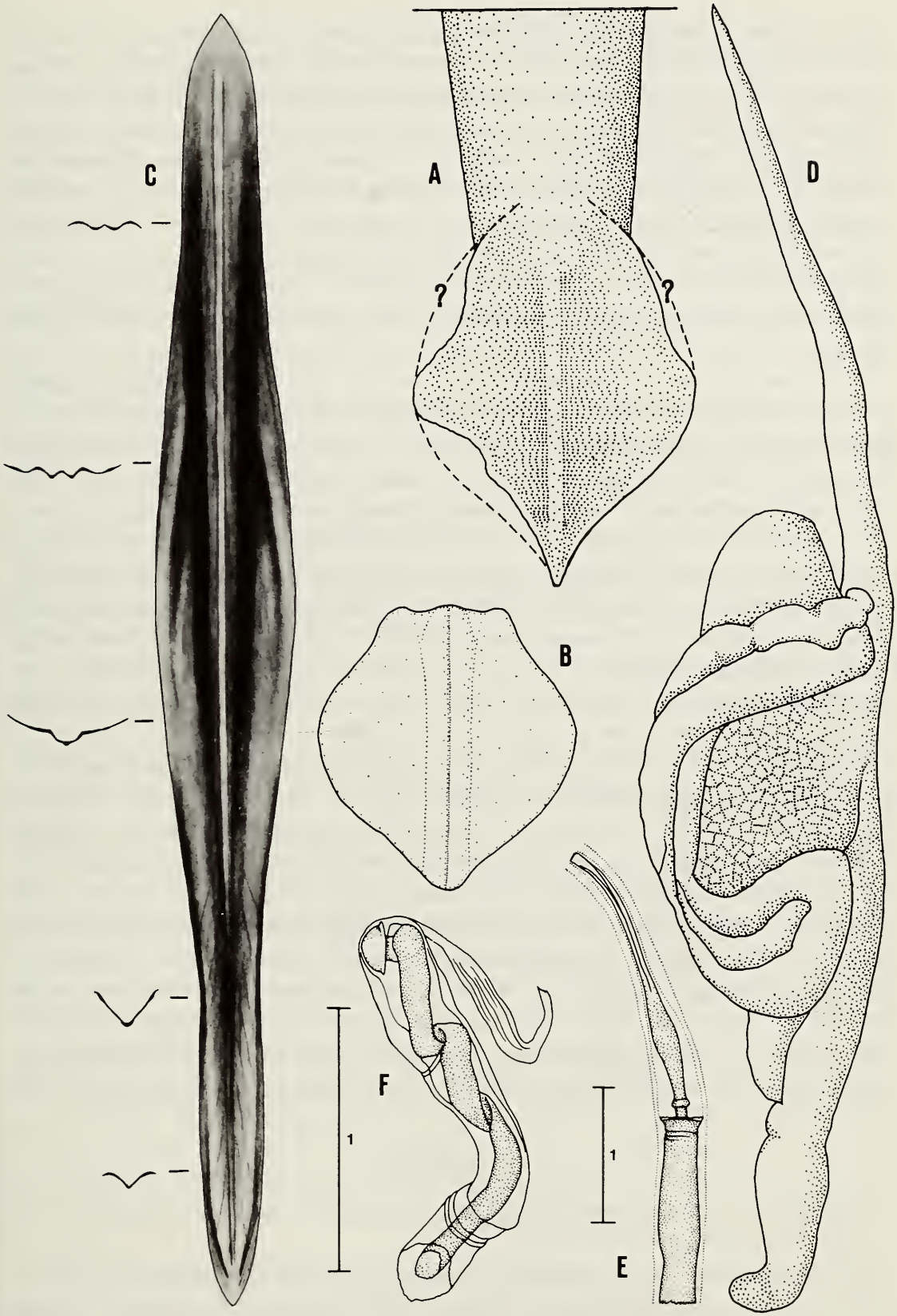

Fig. 1. *Architeuthis* sp. UMML 31.1761: A, Dorsal view of fins and posterior mantle; B, Nuccal cartilage; C, Ventral view of gladius with cross sections; D, Male genitalia (testis and vas deferens not shown); E, Spermatophore, junction of cement body and ejaculatory apparatus; F, Cap region of same. Scales in mm.

Viscera damaged but identifiable; *gills* long with approximately 50 pairs of lamellae; gills broad proximally, narrow distally; base of gills lie anterior to mantle midpoint; *esophagus* long, narrow, entering thin-walled stomach that is subequal in size to *spiral caecum*; *caecum* thin-walled, long, enlarged anteriorly, tapering posteriorly; *digestive gland* bulbous, length approximately 1.5 times greatest diameter of spiral caecum; *rectum* thin-walled, tapering towards *anus* that possesses 2 *anal flaps*; *ink sac* sub-triangular, narrowing to stout ink duct that inserts near anus.

Stomach and caecal contents were examined. Remains of cephalopods (soft tissue, gladius fragments) and fishes (lens, vertebrae, other bones) were found.

Testis lanceolate, 61 mm long, 24 mm wide, 5 mm thick, bevelled towards margins; *vas deferens* damaged; spermatophore glands coiled into flattened ovoid capsule, 31 mm long, 17 mm wide, 13 mm thick; *Needham's sac* subequal in length to spermatophore glands, tapering to point anteriorly with small posterior diverticulum that extends at 90° to long axis of sac; *penis* 60 mm long, 3 mm wide, tapered distally, communicates through anterolateral wall of Needham's sac; penis elliptical in cross section basally, becoming teardrop-shaped medially; firm, cylindrical ridge originates inside Needham's sac and continues along proximal ⅓ of inner wall of penis; ridge bears longitudinal groove; anteriorly ridge and groove become less pronounced; external crenulate keel begins at terminus of internal ridge and continues to within 5 mm of penial tip (Fig. 1D).

Fragments of 2 ruptured *spermatophores* were present, one in Needham's sac, one in the spermatophoric duct. They are characterized as follows: sperm mass cylindrical, without sculpture; cement body cylindrical, slightly narrower than sperm mass, flared at oral end to form collar (damaged aborally); ejaculatory apparatus arises from center of collar, tubular, ¼ diameter of cement body, with prominent annulus short distance oral of cement body; ejaculatory apparatus widens orally then narrows abruptly to thin tube (damaged orally); spiral structure present on aboral portion of ejaculatory apparatus (Fig. 1E); cap slightly enlarged, contains 3 irregular loops of inner tube of ejaculatory apparatus; cap thread strap-like, transparent, with fine longitudinal striations, offset slightly from apex of cap (Fig. 1F).

Discussion

Identification of the present specimen as *Architeuthis* sp. was based on several morphological characters.

The morphology of the gladius is in good agreement with that of a specimen of *A. japonica* described by Sasaki (1929:226, pl. XX, fig. 11). Damage to the posterior tip of the gladius of our specimen prevented determining the presence of a conus as shown by Sasaki. The gladius figured for *Ar-*

chiteuthis sp. by Roper and Young (1972:Fig. 1C) also is similar to our material. The two gladii differ substantially only in the width of the posterior ¼. This may be an artifact of interpretation of the degree of ventral curvature, a difficulty inherent in the illustration of gladii. This same discrepancy is apparent in the gladius of *Architeuthis* sp. (=*A. japonica, fide* Pfeffer, 1912) illustrated by Mitsukuri and Ikeda (1895, pl. X, fig. 2). The gladius of *A. dux* illustrated by Steenstrup (1889, pl. 4), while often referred to in later literature, is too diagrammatic for adequate comparison.

The gill lamellae count of 50 for our specimen agrees closely with the counts of 50 and 55 reported for *Architeuthis* spp. by Roper and Young (1972). The male architeuthid noted earlier (UMML 31.1762) has approximately 57 gill lamellae.

The fin length index of 48 from our specimen appears somewhat large in comparison to most other records from *Architeuthis*. If GL is substituted for ML in the computation of this index, a reasonable alternative in the case of a damaged mantle, an index of 45 results. This value drops to approximately 43 if the assumption is made that actual ML must exceed GL in an intact specimen as suggested by the measurements of *Architeuthis harveyi* (Cadenat, 1936) and *Architeuthis* sp. (Rae, 1950). Our reevaluated indices fall within the known range of FLI values reported for the genus. These values include 39 for *Architeuthis clarkei* (Robson, 1933) and *A. japonica* (Mitsukuri and Ikeda, 1895), 45 for *Architeuthis* sp. (Clarke, 1962), and 48 for *A. physeteris* (Joubin, 1900).

This same rationale can be applied to our FWI of 40. In this case the FWI value is reduced to 37 or 36, only slightly exceeding the value of 33 for *Architeuthis* sp. (Kjennerud, 1958).

To date, the male genitalia of *Architeuthis* have not been described or illustrated satisfactorily. A posterior diverticulum of Needham's sac, as described above, was noted both in our specimen and the larger architeuthid in the University of Miami collections (UMML 31.1762). To our knowledge, this structure is not found in any other oegopsid and may prove to be a character diagnostic of the family.

The grooved ridge noted in Needham's sac and the penis is similar to the ridge and groove system found in the spermatophore glands of *Loligo pealei* used to move the forming spermatophore (Drew, 1919). The structure described here may function in the transport of spermatophores from the storage organ into and down the penis. It is possible that the elongate penis acts as an intromittent organ, with the keel providing strength and aiding in orientation.

The description of spermatophore morphology must be regarded with caution. Ruptured spermatophores often show morphological artifacts. For this reason, comparison with illustrations of other architeuthid spermatophores (Voss, 1956, Fig. 10C; Knudsen, 1957, Fig. 3) is impossible.

The uniqueness of this specimen prompts a reconsideration of the life history of members of this family. Several hypotheses may be formulated.

1) The specimen represents a new taxon of architeuthid that does not attain large size.

2) The specimen indicates that maturation may be followed by substantial growth. That is, growth may continue for some period following the onset of spermatophore production. There is evidence to support this hypothesis. Spermatophore measurements from members of the Lepidoteuthidae, Histioteuthidae, and Cranchiidae show that a range of spermatophore sizes can occur within a single male (Hess, in prep). This condition has been noted also in the Architeuthidae (Knudsen, 1957; Kjennerud, 1958; Hess, in prep.). Given that spermatophore length is related to mantle length (Drew, 1919; Hess, in prep.), these measurements would suggest the production of spermatophores over an extended period of time, during which the animal has grown. A second, less likely alternative is that the animal does not grow appreciably, but that the spermatophore glands alone have increased in size.

Conversely, spermatophore measurements from members of the Loliginidae, Pickfordiateuthidae, Ommastrephidae, and Enoploteuthidae show far less variability in size. This situation could arise if the animals grew little during spermatophore production or if multiple mating occurs. In the latter case, spermatophores produced between successive copulations would be more nearly equal in size. Data concerning the reproductive behavior of squids is limited, but observations of *Loligo opalescens* by McGowan (1954) indicate that males die after copulation. If this is the case in the Oegopsida, multiple copulation cannot explain the consistency found in spermatophore sizes.

3) The specimen is an aberrant individual exhibiting precocious maturation and is without further significance in considerations of the usual life history of architeuthids. Precocious maturation has been observed in the squid *Loligo* (*Doryteuthis*) *plei* (Hixon, pers. comm.). Cohen (1976) also reported small mature *L. plei,* but did not regard these specimens as examples of precocious maturity.

While the first two hypotheses are not mutually exclusive, the paucity of material precludes determination of the validity of either. Although it cannot be discounted, the authors feel that the third hypothesis is least likely.

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